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Investigations of Y_2SiO_5: Nd^{143} by ESR method

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ABSTRACT

Here we present the investigation of Y_2SiO_5 monocrystals doped by isotopically pure $^{143}Nd^{3+}$(0.025%) impurity by X-ray and electron spin resonance methods. The crystal structure parameters of Y_2SiO_5 monocrystal and microscopic parameters: g-tensors and hyperfine structure parameters of two nonequivalent Nd^{3+} paramagnetic centers were determined.

1. Introduction

One of the research areas in the field of advanced materials and their applications modern information technologies of processing and transmission of information through a quantum memory modules is the study of dielectric crystals activated by rare-earth ions. To create high-performance modules can be used the group of crystals, to which Y_2SiO_5:$^{143}Nd^{3+}$ belongs. These crystals have properties, required to create highly efficient optical quantum memory, namely, large optical density, and large phase relaxation times, the presence of long-lived hyperfine states [1].

The aim of this work was to study the paramagnetic centers of neodymium ion doped in the Y_2SiO_5 single crystals by ESR method.

2. Samples preparation and experiment technique

In this work we study the physical properties of Y_2SiO_5:$^{143}Nd^{3+}$ monocrystals by X-ray and electron spin resonance (ESR) methods. The X-ray diffraction pattern of the sample was obtained using a DRON-7 diffractometer equipped with the CuK_α radiation source. The system was calibrated using a Standard Reference Material 300,104 (annealed nickel foil). The diffractometer parameters were 40 kV, 20 mA, a 2θ scan range of 10–110°, step size of 0.02° and a scan speed of 5 s/step. Electron spin resonance (ESR) measurements were carried out on a Bruker EMX/plus spectrometer equipped with continuous-flow He cryostats (Oxford Instruments) at X- (9.4 GHz) frequency in the temperature range 5–40 K. The samples were oriented by x-ray diffraction and cut in the (a^*b), (a^*c), and (bc) perpendicular planes to form rectangular parallelepipeds measuring 1.5×2×3 mm. Monocrystal samples of Y_2SiO_5 were synthesized in Prokhorov General Physics Institute of the Russian Academy of Sciences (GPI RAS) (Moscow, Russia). All crystals have been grown in irridium crucibles with a diameter of 40 mm by the Czochralski method at industrial installations with induction heating “Crystal-2″ and “Crystal-3 M”.

3. Experimental results and discussion

The X-ray analysis of the Y_2SiO_5 monocrystal showed that the compound is in single-phase state and its structure belongs to the space group C2/c, lattice parameters are a = 10.410 Å; b = 6.721 Å; c = 12.490 Å, $\alpha = 90°$, $\beta = 102.65°$, $\gamma = 90°$ and in agreement with literature data [2]. Yttrium ions in the unit cell are located in two positions in Y(1) and Y(2). One of them is substituted by Nd^{3+}(see Fig. 1a and b). The diffraction pattern of the sample is shown in Fig. 1c. The atom position parameters are listed in Table 1.

The observed ESR spectrum Nd^{3+} in Y_2SiO_5 exhibits two groups of eight nonequidistant lines, which represent the hyper fine structure (HFS) components due to the odd neodymium isotope ^{143}Nd for two magnetically nonequivalent positions Nd(1) and Nd(2); the line from the even isotope is absent. The positions of observed ESR lines does'not demonstrate the temperature dependance in the temperature range 5 K < T < 20 K. Fig. 2 presents angular dependencies of HFS lines recorded in (a^*b) and (a^*c)-planes, respectively; a^* denotes the direction perpendicular to the crystallographic (bc) plane. To fit the experimental data we used the effective electron spin S=1/2 and the nuclear spin I=7/2 for ^{143}Nd and the following Spin Hamiltonian:

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